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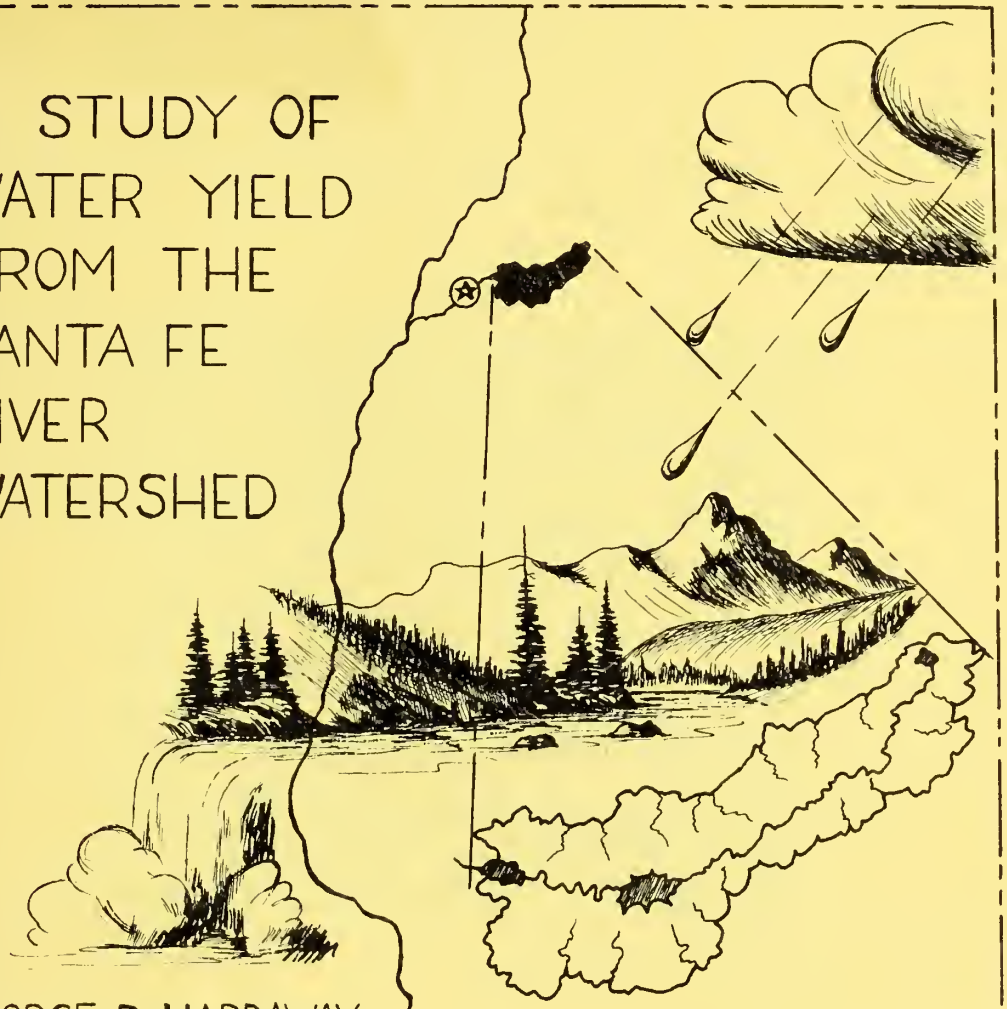
A STUDY OF WATER YIELD FROM THE SANTA FE RIVER WATERSHED



BY
GEORGE D HARDAWAY
AND
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by

George D. Hardaway[1] and J. Robert Thompson[2]

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INTRODUCTION

Since availability of water limits activities in the arid Southwest, all management aspects of the water resource must be explored. This study of the Santa Fe River watershed[3] was to find out whether change in land use affected water yield, and to determine basic precipitation-runoff relationships for that watershed.

In the New Mexico portion of the Rio Grande Basin, the spruce-fir and ponderosa pine zones make up 30 percent of the land area and provide 72 percent of the streamflow. As well as supplying a major part of the water supply, these mountain areas provide the timber, much of the recreational use, two-thirds of the big-game crop, and one-third of the livestock grazing use on the National Forests in New Mexico. Management practices must be compatible with all resource uses in the area.

HISTORY OF THE AREA

The Santa Fe River watershed, a portion of the Rio Grande Basin, has a history of heavy use followed by an extended period of nonuse (figs. 1 and 2). Streamflow records were kept for parts of both periods. An 1883 fire was the last one recorded on the watershed, and little evidence remains.

During 1915-17, 2,500 acres of ponderosa pine were logged. The watershed supplied firewood, logs, and vigas from the time of the Indian settlers to 1930. However, because of inaccessibility, the use probably never extended up the canyon beyond McClure Reservoir.

When the U. S. Forest Service conducted a grazing reconnaissance in 1922, only 40 cattle, which had drifted from private lands, were found in the canyon area. Since vegetation was sparse, the stream channel badly eroded, and the domestic water supply polluted with sediment, the Forest Service recommended closing the area to protect the watershed. In 1926, the National Forest area was fenced and closed to grazing.

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[3] "The Santa Fe River watershed" considered in this report refers to the headwater portion only, and not to the entire drainage basin.

Figure 1. --A steep hillside in Santa Fe River canyon.
A, Eroded condition in 1916; B, Same area in 1955.

Figure 2. --Streambottom vegetation on the Santa Fe River watershed. A, In 1936, after 10 years of protection; B, Same area in 1958.

By authority of a State Enabling Act, the City of Santa Fe, in 1930, passed a watershed protection ordinance, but the provisions applied only to the lower portion of the watershed adjacent to the city limits.

A 1932 cooperative agreement, signed by the U. S. Department of Agriculture, the New Mexico Power Company, and the City of Santa Fe, provided for protection from grazing, cutting, and other uses. Also in 1932, the Secretary of Agriculture issued an order closing the canyon to human use, except city, county, State, and Federal administrative personnel, and persons who owned land in the canyon.

DESCRIPTION OF THE AREA

The Santa Fe River watershed is located within the Santa Fe National Forest, east and north of the city of Santa Fe, New Mexico, in the Sangre de Cristo mountains (fig. 3). A stream gaging station (station No. 3 on fig. 3), is located at the lower edge of the ponderosa pine type. Above the gaging station is 18.2 square miles of steep and rough terrain, 90 percent of which is covered with conifers. The upper slopes support dense stands of Engelmann spruce, while bottomlands are covered by thickets of willow and alder or scattered groves of aspen, blue spruce, white fir, and Douglas-fir. The only nontimbered areas are a few small meadows in the headwaters and a narrow strip of streambank shrubs in the canyon bottom.

At its headwaters near Lake Peak, the stream is fed by Santa Fe Lake. From that point, at an elevation of 11,500 feet, the stream travels 9.2 miles to the gaging station with a drop in altitude of 3,800 feet. Average slope for that distance is 8 percent. Flow at the stream gage is regulated by McClure Reservoir which is approximately 0.4 mile upstream from the gage. The length of the drainage basin is 9.5 miles; its average width is 2.2 miles, and maximum width is 3.8 miles. Eighty percent of the drainage area has slopes facing west or east, and slopes on more than 65 percent of the total area exceed 40 percent (table 1).

Table 1.--Slope and exposure of the Santa Fe River watershed

Slope class (Percent)	Slope exposure				
	East	West	South	North	Total
	Percent of area				
0-10	2.3	0.7	0.9	0	3.9
11-20	.9	5.4	0	0	6.3
21-30	0	6.0	0	.8	6.8
31-40	.7	15.9	.5	.5	17.6
41-50	2.0	4.7	8.0	6.8	21.5
51-64	23.6	15.7	1.6	0	40.9
65-80	0	3.0	0	0	3.0
Total	29.5	51.4	11.0	8.1	100.0

The underlying rock is granite and schist of Precambrian age. The soils are colluvial or residual, with a small area of alluvium at the lower extremities of the basin. Deep soils with the "B" horizon poorly defined or absent are typical of this area.

Though no long-term records of precipitation on the watershed are available, short-term records kept by the Public Service Company of New Mexico indicate an average annual precipitation of about 25 inches (tables 2 and 3).

Table 2. --Precipitation records from the Elk Cabin gage on the Santa Fe River watershed, New Mexico

Date	Precipitation		Date	Precipitation	
	Calendar Year	Water Year[1]		Calendar Year	Water Year[1]
	- - - Inches - - -			- - - Inches - - -	
1947	15.30	13.10	1953	19.00	17.00
1948	17.40	19.05	1954	21.50	25.50
1949	21.75	19.25	1955	19.25	17.70
1950	11.00	13.50	1956	--	13.20
1951	20.50	16.50			
1952	--	--	Average	18.21	17.20

[1] October 1st of previous year to October 1st of year listed.

Table 3. --Precipitation records from the Santa Fe Lake gage on the Santa Fe River watershed, New Mexico

Period	Precipitation	Period	Precipitation
	Inches		Inches
6/11/47 to 10/16/47	9.80	6/5/53 to 9/30/53	9.40
10/16/47 to 6/30/48	[1]11.00	9/30/53 to 6/3/54	16.50
6/30/48 to 10/1/48	5.25	6/3/54 to 10/5/54	15.90
10/1/48 to 6/15/48	16.25	10/5/54 to 6/16/55	18.50
6/15/48 to 10/13/49	4.50	6/16/55 to 10/5/55	[1]12.00
10/13/49 to 9/29/50	15.00	10/5/55 to 5/31/56	11.90
9/29/50 to 6/1/51	14.00	5/31/56 to 10/1/56	6.00
6/1/51 to 9/24/51	10.30	10/1/56 to 5/31/57	--
9/24/51 to 6/5/52	19.40	5/31/57 to 10/4/57	[1]14.00
6/5/52 to 10/8/52	9.40	10/4/57 to 6/13/58	24.50
10/8/52 to 6/5/53	20.65	Annual average	26.4

[1] Approximate values.

METHODS

PRECIPITATION DATA

Because precipitation measurements from the watershed are limited, records from the closest urban weather stations were used in the analyses. The nearest U. S. Weather Bureau precipitation gages with long-term records are located at Santa Fe and Las Vegas, New Mexico. Both stations are 20 miles from the watershed; Las Vegas is east of the mountains, while Santa Fe is west.

The only records of precipitation on the watershed are from two standard 8-inch U. S. Weather Bureau storage-type gages, presently operated by the Public Service Company of New Mexico. The "Elk Cabin" gage (table 2) is located approximately 2 miles upstream from McClure Reservoir at an elevation of 8,000 feet. The "Santa Fe Lake" gage (table 3) is located one-fourth mile below Santa Fe Lake at an elevation of 11,500 feet.

STREAMFLOW DATA

The earliest continuous stream gaging records, collected by the New Mexico State Engineer, date from April 1913. From that time until November 1930, the gaging station was located at the present site of Nichols Reservoir (fig. 3, station No. 1).

From November 1930 to October 1947 the stream gaging site was located 300 feet downstream from McClure dam (fig. 3, station No. 2). Since 1947 the station has been located at its present site, 0.4 mile downstream from McClure Reservoir, (fig. 3, station No. 3).

Watershed areas above the three gaging stations, as measured from a USGS quadrangle, are as follows:

Gaging Station No.	Area (sq. miles)
1	22.0
2	17.5
3	18.2

Because streamflow is regulated by McClure Reservoir, information on the reservoir water elevations was compiled in order to correct the runoff figures for storage and release at the reservoir. Water-elevation records are kept by the Public Service Company of New Mexico. No records were available for the period 1926-31. In order to make corrections for evaporation losses, area-volume relationships of the reservoir were determined with data obtained from the Public Service Company of New Mexico.

McClure Reservoir, formed by an earth-fill dam, was first operated in 1926 with a capacity of 561 acre-feet. It was then called Granite Point Reservoir. In 1935, the dam was raised 6 feet, bringing the capacity to 750 acre-feet. Again in 1947, the dam was raised to permit additional storage. Its total capacity to the top of the flashboards is now 3,060 acre-feet.

During the dry years prior to 1947, water was pumped from Santa Fe Lake to augment natural streamflow. No records of the volume of that water were kept; however, judging from the size of the lake, it probably did not amount to more than 1 or 2 percent of the annual runoff, since the total capacity of the lake is only 4 or 5 percent of annual streamflow.

DATA ADJUSTMENTS

In the absence of long-term records on the watershed, the averaged precipitation records for Las Vegas and Santa Fe were used to indicate annual variation in the actual precipitation on the watershed. The average of these stations fell short of the actual watershed amount and can only be considered an index to the actual precipitation. For the period of record (since 1947) at the Elk Cabin and Santa Fe Lake gages, the precipitation at Las Vegas and Santa Fe averaged 13.2 inches compared to 22.1 inches on the watershed.

Monthly streamflow was corrected for difference in reservoir storage occurring during the month. If the change in reservoir content was downward (indicating release), this amount was subtracted from the stream-gage runoff amount. If the change in content showed an increase, the amount of the increase was added to streamflow.

To correct for evaporation losses at the reservoir, an amount equal to 70 percent of the evaporation from a class A Weather Bureau pan at Santa Fe was used. This amount was computed by months for 1917-26 (the only years of record).[4] By applying the average monthly evaporation (multiplied by 0.70) to the mean monthly lake surface area, the monthly evaporation losses were determined. These amounts were then added to the monthly runoff. This correction for evaporation averaged 175 acre-feet per year. Because the lake surface was relatively small prior to 1947, the evaporation correction was not applied during that period.

Since runoff records were from three different gaging sites, these data were adjusted to a common area to allow comparison of water yields before and after protection. To facilitate continuation of the study, the adjustment was made on the basis of the area above the present stream gage.

Total runoff for the 12-year period (1914-25) on the 22-square-mile area was 103,680 acre-feet. Adjustment on a direct areal basis to the 18.2-square-mile area gave 85,770 acre-feet. This was an over-correction because the 3.8 square miles received less precipitation and produced less runoff per unit area than the entire watershed. The actual yield for this period, from the 18.2-square-mile area, was between 103,680 acre-feet and 85,770 acre-feet.

The average yearly runoff from the 22-square-mile area during the 12 years was 8,640 acre-feet per year, or 393 acre-feet per square mile per year. Runoff for the 3.8 square miles below the upper gage would probably average about 200 acre-feet per square mile per year.

Using the yield figure of 200 acre-feet per square mile per year for adjustment purposes, water production from 18.2 square miles for the 12-year period was computed to be 94,570 acre-feet (table 4).

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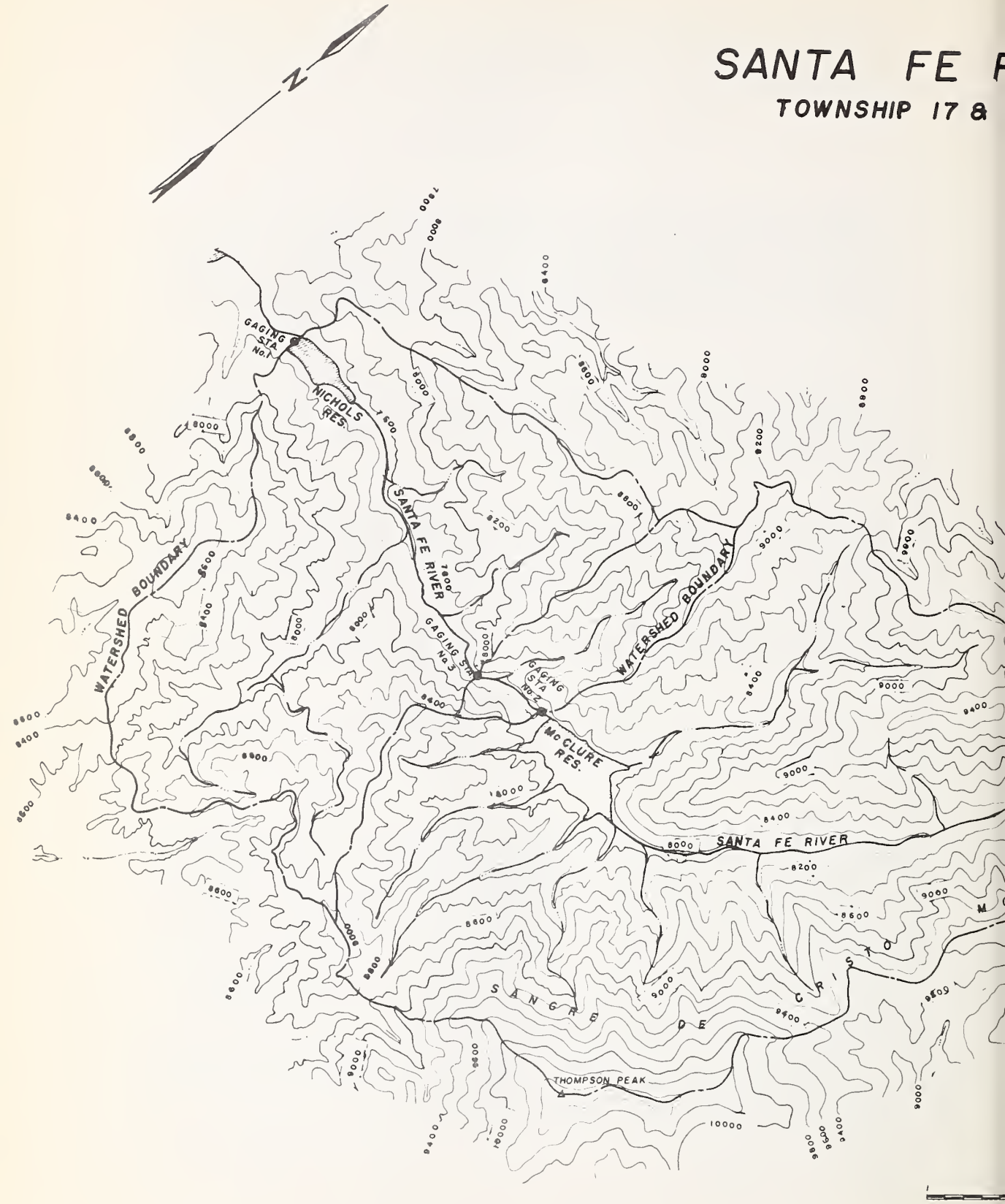
[4] Climatological Summary, New Mexico, N. Mex. State Engin. Office Tech. Rpt. 5. 1956.

SANTA FE R

TOWNSHIP 17 &



WATERSHEDS

RANGE II EAST

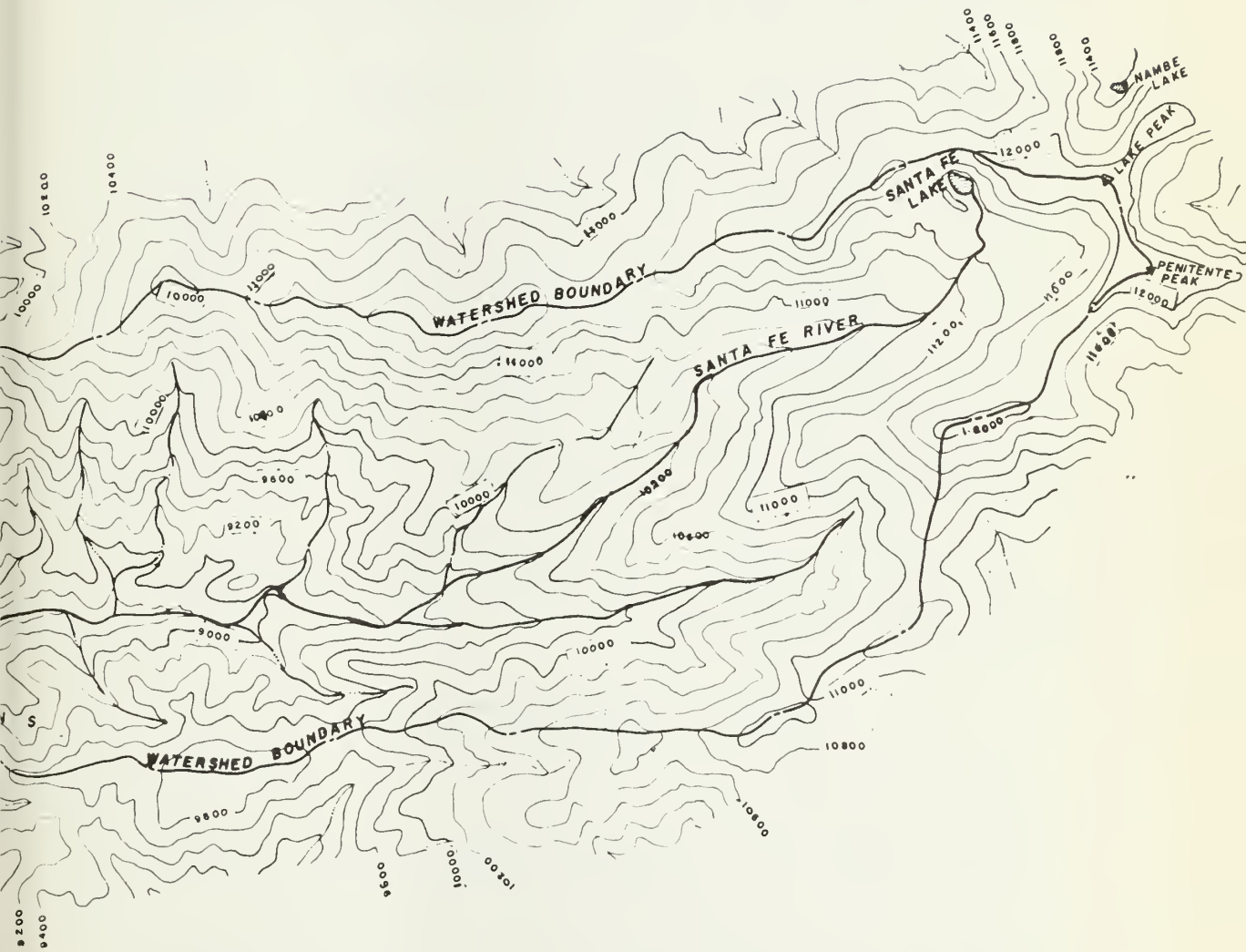


Figure 3.

SANTA FE RIVER WATERSHEDS

TOWNSHIP 17 & 18 SOUTH, RANGE 11 EAST

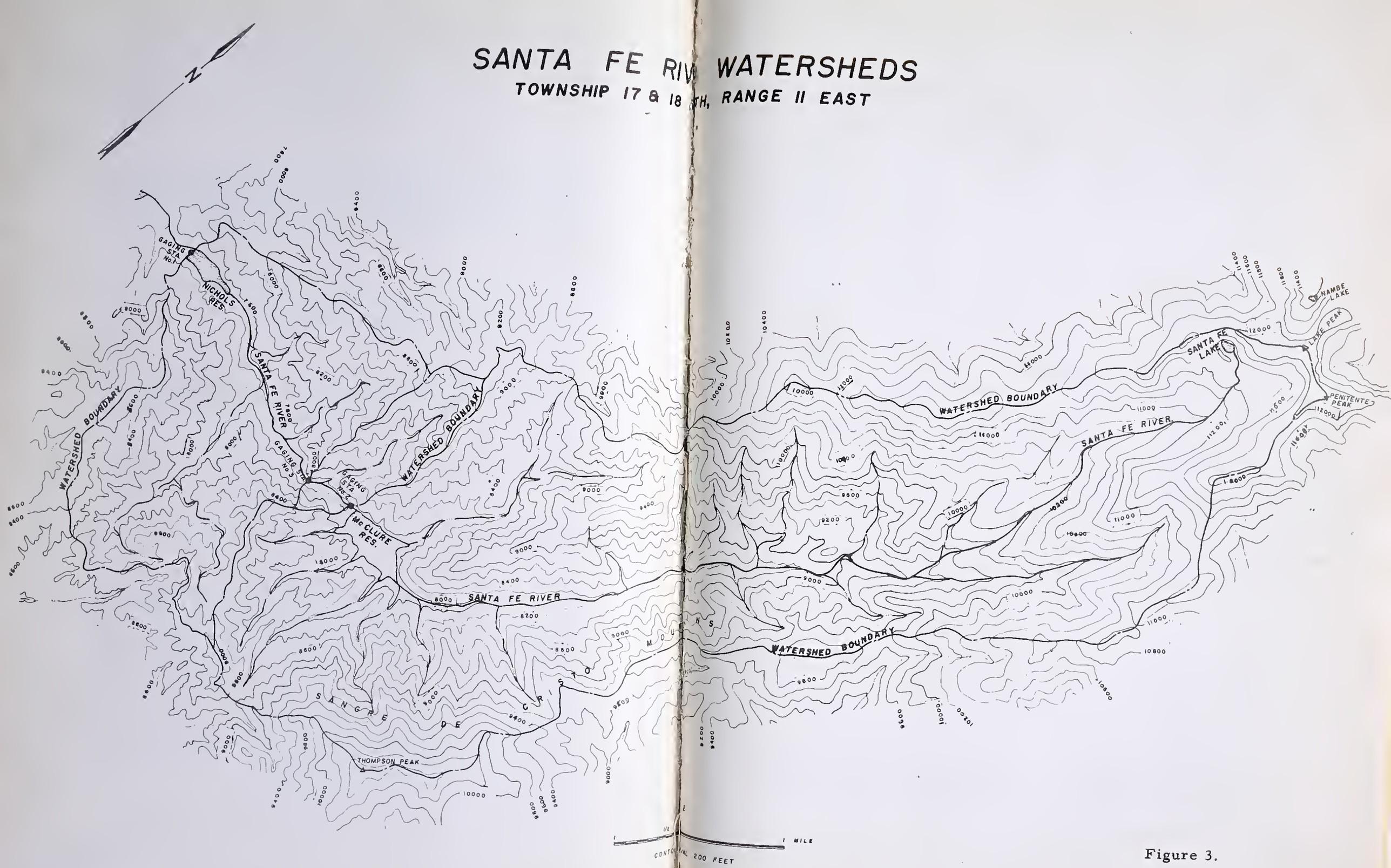


Figure 3.

Table 4. --Adjusted streamflow on Santa Fe watershed, New Mexico, 1914-25

Calendar Year	Actual Flow	Correction[1]	Adjusted Flow	Adjusted Flow[2]
	- - - - - M acre-feet - - - - -			Area Inches
1914	8.80	0.77	8.03	8.27
1915	12.50	1.10	11.40	11.75
1916	13.21	1.16	12.05	12.42
1917	2.58	.23	2.35	2.42
1918	4.92	.43	4.49	4.63
1919	19.94	1.75	18.19	18.74
1920	6.99	.61	6.38	6.57
1921	16.66	1.47	15.19	15.65
1922	3.32	.29	3.03	3.12
1923	5.18	.46	4.72	4.86
1924	7.62	.67	6.95	7.16
1925	1.96	.17	1.79	1.84
Total	103.68	9.11	94.57	97.43

[1] 200 A. F. / sq. mi. / yr. on 3.8 sq. mi. for 12 years = 9,120 A. F.
Total runoff from 22-sq. mi. area for 12 years = 103,680 A. F.

$\frac{9,120}{103,680}$ = 0.087963; correction = 0.087963 times actual flow, or

adjusted flow = 0.912037 times actual flow.

[2] Converted to area inches on the basis of 18.2 sq. mi.

Runoff for the period 1932-47 was not adjusted to the 18.2 square miles because the difference in size of gaging areas for that period and the period since 1947 was only 0.7 square mile.

FINDINGS AND DISCUSSION

Basic precipitation and streamflow data used in the analysis are listed in tables 5 and 6, respectively.

Figure 4 compares mean monthly precipitation and runoff. Figure 5 indicates the relationship between precipitation and runoff.

Summer thunderstorms contribute to yearly water yield. In some years this amounts to 50 percent of the total runoff. Of the 38 years of record used in the analysis, 26 have well-defined summer peaks on the annual hydrograph, and half of the remaining years show minor summer flow.

Table 5.--Annual precipitation computed from records at Las Vegas and Santa Fe, New Mexico, 1914-57

Year	Calendar Year	Water Year	Year	Calendar Year	Water Year
	Inches			Inches	
1914	19.01	17.44	1939	14.42	14.45
1915	17.86	20.17	1940	17.20	15.80
1916	16.44	14.78	1941	25.00	24.98
1917	6.78	9.52	1942	16.58	17.19
1918	15.81	11.26	1943	9.83	10.50
1919	23.89	26.07	1944	13.84	12.39
1920	16.54	16.98	1945	10.72	13.24
1921	20.98	22.16	1946	17.00	15.00
1922	12.72	12.44	1947	10.72	10.98
1923	16.85	13.54	1948	15.84	17.09
1924	10.00	13.11	1949	20.03	20.86
1925	14.08	12.71	1950	11.39	11.91
Average			1951	10.31	9.26
1914-25	15.91	15.85	1952	13.18	13.00
1932	17.32	17.92	1953	12.56	11.09
1933	13.68	13.24	1954	14.10	14.40
1934	12.10	11.96	1955	11.22	12.50
1935	18.94	18.92	1956	6.48	7.44
1936	11.94	13.26	1957	19.25	13.82
1937	15.96	16.28	Average		
1938	16.40	14.93	1932-57	14.46	14.32

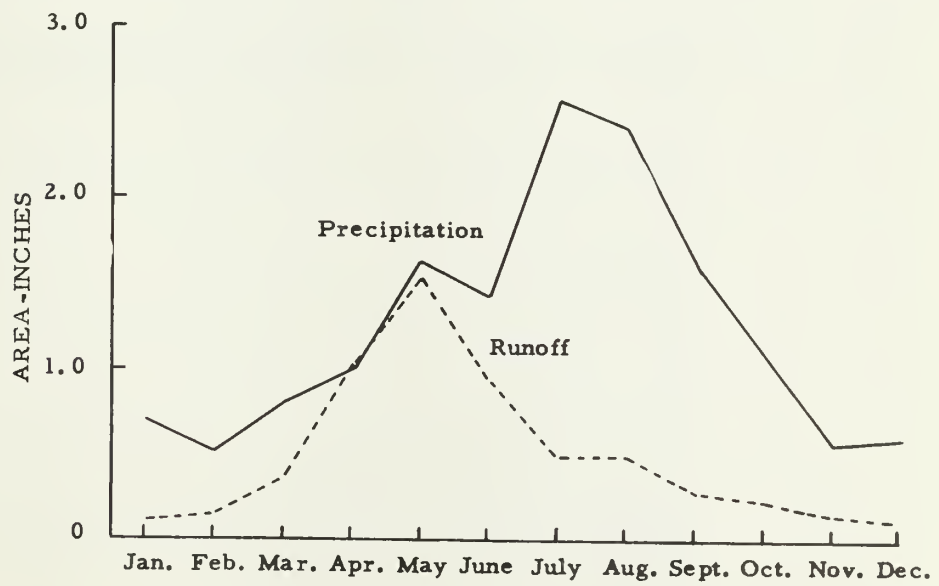


Figure 4.--Mean monthly precipitation and runoff, averaged for the 38 years of record.

Table 6.--Runoff from Santa Fe watershed, New Mexico, 1913-25, 1931-57 (no records available 1926-31)

Date	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Total for-- Water year	Calendar year	Water year	Calendar year
	Acre-feet														Inches	
GAGING STATION NO. 1, 1913-25[1]																
1913-14	327	246	301	180	205	516	1,090	1,830	1,000	1,590	1,030	362	8,677	8,798	7.40	7.50
1914-15	425	349	221	172	231	749	4,080	2,600	2,150	1,200	645	227	13,049	12,499	11.12	10.65
1915-16	183	126	136	353	816	1,840	2,430	3,400	1,820	774	476	260	12,614	13,207	10.75	11.26
1916-17	598	270	170	215	186	149	201	559	589	224	147	109	3,417	2,578	2.91	2.20
1917-18	75	72	52	60	126	482	596	1,210	980	464	391	227	4,735	4,921	4.04	4.19
1918-19	144	122	119	126	133	615	3,620	5,170	3,090	3,450	1,680	719	18,988	19,936	16.18	16.99
1919-20	683	321	329	175	333	352	939	2,760	1,340	339	214	120	7,905	6,989	6.74	5.96
1920-21	57	186	174	158	246	282	494	1,860	4,470	3,110	4,550	1,030	16,617	16,661	14.16	14.20
1921-22	183	155	123	134	109	255	875	999	465	164	70	61	3,593	3,322	3.06	2.83
1922-23	46	57	87	103	148	273	741	1,720	870	207	308	233	4,793	5,175	4.08	4.41
1923-24	158	232	182	143	133	504	2,080	2,520	1,240	336	215	199	7,942	7,618	6.77	6.49
1924-25	113	60	75	94	113	215	339	177	63	128	244	161	1,782	1,961	1.52	1.67
1925	168	149	110													
Total	2,833	2,099	1,778	1,913	2,779	6,232	17,485	24,805	18,077	11,986	9,970	3,708	104,112	103,665	88.73	88.35
Average	236	175	148	159	232	519	1,457	2,067	1,507	999	831	309	8,676	8,639	7.39	7.36
GAGING STATIONS NO. 2 AND 3, 1931-57[2]																
1931-32	820	220	165	140	344	515	1,459	1,990	734	326	458	417	7,588	6,778	8.13	7.26
1932-33	180	128	87	75	79	130	173	485	815	394	150	115	2,811	2,763	3.01	2.96
1933-34	105	149	93	51	105	79	223	311	131	135	207	346	1,935	1,979	2.07	2.12
1934-35	201	104	86	82	103	160	358	1,730	1,570	281	765	707	6,147	6,407	6.59	6.86
1935-36	323	184	144	116	88	469	1,080	1,500	468	515	1,103	311	6,301	6,638	6.75	7.11
1936-37	569	275	144	138	110	383	1,450	2,090	1,400	467	213	352	7,591	6,977	8.13	7.48
1937-38	115	180	79	62	109	131	313	702	396	383	197	239	2,906	3,126	3.11	3.35
1938-39	298	157	139	139	127	631	1,216	1,324	277	164	268	221	4,961	4,890	5.32	5.24
1939-40	261	146	116	117	177	781	1,084	1,440	515	138	279	277	5,331	5,358	5.71	5.74
1940-41	221	143	186	219	337	772	1,540	5,710	2,960	913	444	458	13,903	15,815	14.90	16.94
1941-42	1,390	784	288	196	187	372	3,438	3,050	1,511	214	204	511	12,145	10,061	13.01	10.78
1942-43	167	113	98	126	175	392	1,034	1,010	239	201	188	148	3,891	3,797	4.17	4.07
1943-44	118	91	75	79	67	201	570	1,774	1,004	664	416	161	5,220	5,581	5.59	5.98
1944-45	244	190	211	76	258	503	1,370	2,380	850	191	174	234	6,681	6,356	7.16	6.81
1945-46	140	100	80	62	60	224	505	433	140	259	647	262	2,912	3,237	3.11	3.47

1946-47	234	233	178	110	88	180	320	846	492	242	55	511	3,489	3,105	3.74	3.33
1947-48	103	74	84	92	135	406	1,351	1,762	838	259	155	77	5,336	5,301	5.50	5.46
1948-49	106	60	60	50	121	297	1,274	1,896	1,432	646	752	520	7,214	7,470	7.43	7.70
1949-50	259	153	70	60	69	87	199	226	104	133	115	79	1,554	1,214	1.60	1.25
1950-51	58	39	45	30	30	55	91	318	144	51	549	194	1,604	1,649	1.65	1.70
1951-52	68	59	60	83	68	220	1,033	1,647	1,133	233	156	112	4,872	4,864	5.02	5.01
1952-53	75	55	49	83	93	184	249	465	541	293	181	70	2,338	2,403	2.41	2.48
1953-54	65	97	82	60	51	183	400	642	189	87	145	78	2,079	2,006	2.14	2.07
1954-55	81	54	36	59	46	96	182	581	342	203	578	245	2,503	2,600	2.58	2.68
1955-56	88	83	97	76	85	113	160	218	32	20	33	14	1,019	859	1.05	.88
1956-57	34	34	40	57	82	188	681	1,137	1,812	474	1,276	629	6,444	7,692	6.64	7.92
1957	531	517	308													
Total	6,034	4,202	2,935	2,438	3,194	7,752	21,753	35,667	20,069	7,886	9,708	7,288	128,775	128,926	136.52	136.65
Average	232	162	113	94	123	298	837	1,372	772	303	373	280	4,953	4,959	5.25	5.26
COMBINED TOTALS: 1913-25, 1931-57																
Total	8,867	6,301	4,713	4,351	5,973	13,984	39,238	60,472	38,146	19,872	19,678	10,996	232,887	232,591	225.25	225.00
Average	233	166	124	115	157	368	1,033	1,591	1,004	523	518	289	6,129	6,121	5.93	5.92
	Inches															
Average[3]	0.23	0.16	0.12	0.11	0.15	0.36	1.00	1.55	0.96	0.49	0.49	0.29				

[1]Station located at present site of Nichols Reservoir; no storage correction necessary.

[2]From November 1930 through September 1947, station located 300 feet downstream from McClure Dam; figures corrected for reservoir storage. Since October 1947, station located 0.4 mile downstream from McClure Reservoir; figures corrected for reservoir evaporation and storage.

[3]Runoff for the three grazing periods (1914-25, 1932-47, 1948-57) was converted to inches on the basis of their respective areas; these figures were then weighted by the number of years in the period to arrive at mean monthly runoff in inches for the 38 years of record.

A comparison of precipitation data from the various sites showed correlation between yearly amounts of precipitation at all sites. Also, winter precipitation at Elk Cabin was correlated with the average winter precipitation at Santa Fe and Las Vegas. However, no significant correlation existed between Elk Cabin and the average of Santa Fe and Las Vegas for increments of summer precipitation. Eliminating summer flow and relating winter precipitation to spring runoff did not improve the correlations obtained through the use of annual totals.

Various combinations of yearly precipitation and runoff totals were tested by regression. The curvilinear regression of water-year (October 1 to September 30) precipitation and calendar-year runoff (fig. 5) gave the best correlation (R = 0.869).

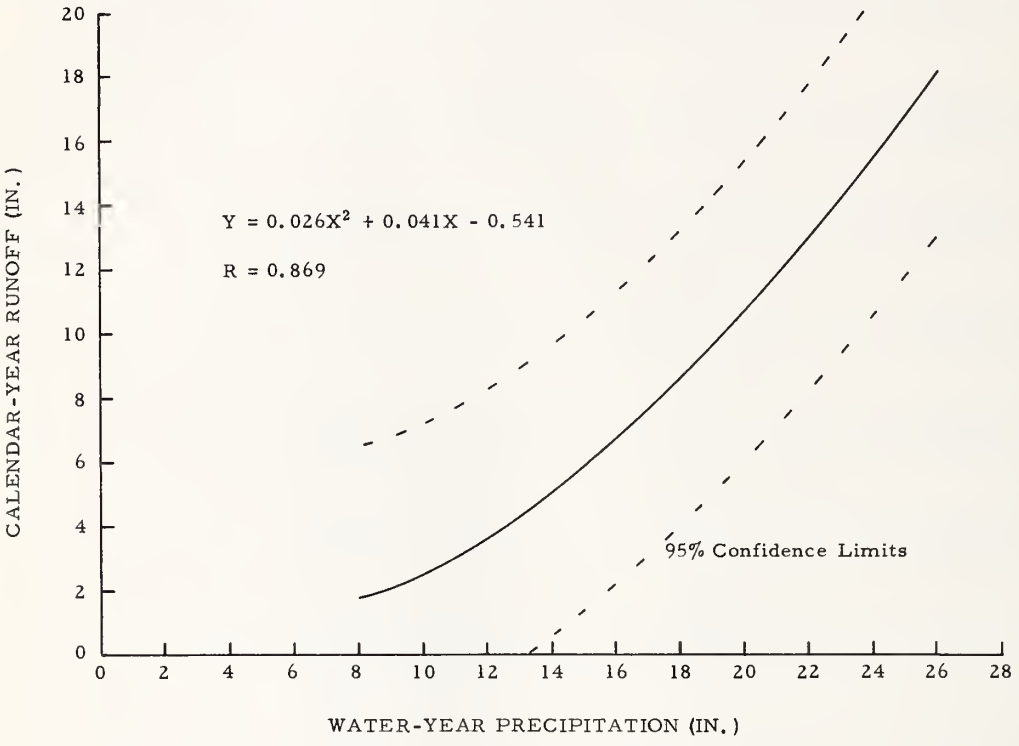


Figure 5. --Curvilinear regression of Santa Fe River runoff and Santa Fe-Las Vegas precipitation (1914-25 and 1932-57).

A plotting of water-year precipitation with time (fig. 6) showed a decrease in precipitation with time. The negative slope of the line and the correlation coefficient (r) were significant only at the 10 percent level, which leaves some doubt whether this apparent decrease is real.

Covariance analysis of the before- and after-treatment periods gave the following breakdown of the difference in water yield between the two periods:

Total difference	-- 2,775 acre-feet
Amount accounted for by differences in precipitation	-- 1,275 acre-feet
Amount unaccounted for	-- 1,500 acre-feet

These amounts were not statistically significant at the 5 percent level; however, they were significant at the 10 percent level.

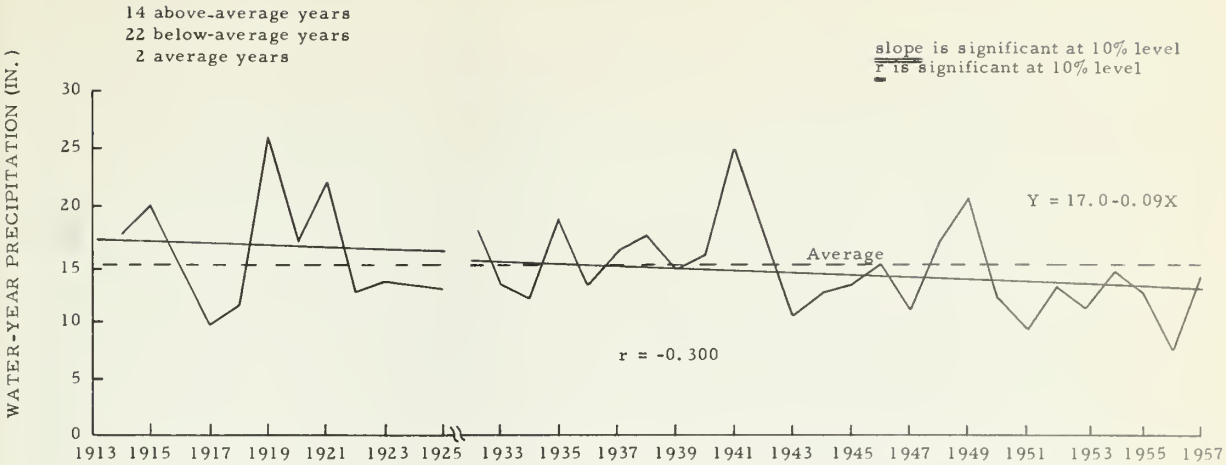


Figure 6. --Precipitation pattern and trend (Santa Fe and Las Vegas).

An alternate approach in analyzing changes in water yield with time (due to protection) was made, using double mass curves.

Double mass plotting of accumulated precipitation against accumulated runoff showed changes in the slope of the curve, which would indicate changes in the precipitation-runoff relationship with time (fig. 7). A comparison of average precipitation and slope of the double mass curve for periods where the slope was approximately constant indicated a strong relationship between slope and precipitation.

Analysis of the double mass curve of precipitation and runoff, with accumulation by ascending order of precipitation, also indicated that the major cause of any change in water yield could be attributed to a change in average annual precipitation over a given period (fig. 8).

CONCLUSIONS

1. Highly significant correlation was found between annual amounts of streamflow and the Las Vegas-Santa Fe precipitation index.

2. Precipitation declined during the study period; consequently, streamflow declined.

3. A decline in streamflow that was a result of factors other than a decline in precipitation, was not statistically significant, even though the average decrease was approximately 1,500 acre-feet per year. However, when the competence of the data available is considered, a quantitative evaluation of the changes in streamflow due to various factors may not be warranted.

4. Summer rainfall is a relatively important source of streamflow from the Santa Fe watershed. The amount of this summer runoff varies from a high of about 50 percent of the yearly total, to a low of zero.

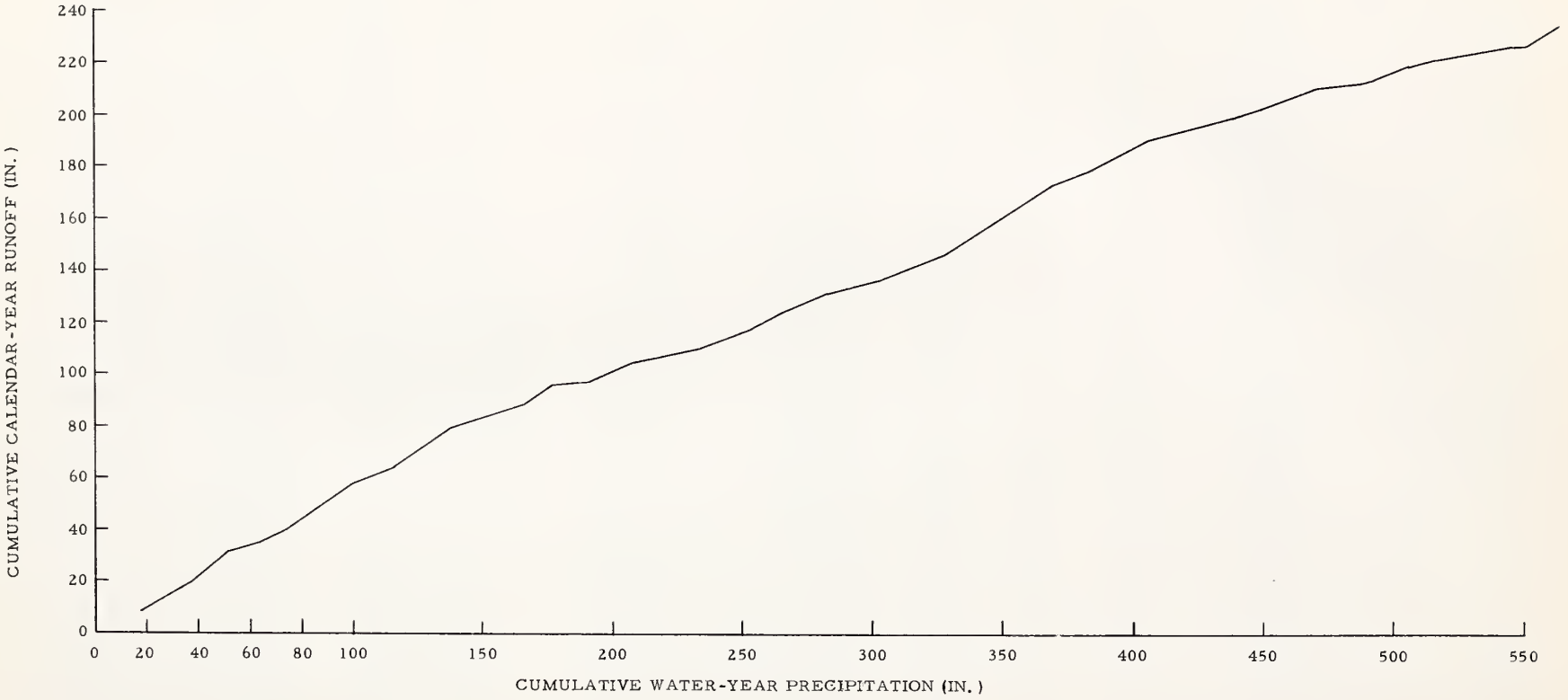


Figure 7.--Double mass plotting of precipitation and streamflow accumulated chronologically (Santa Fe River).

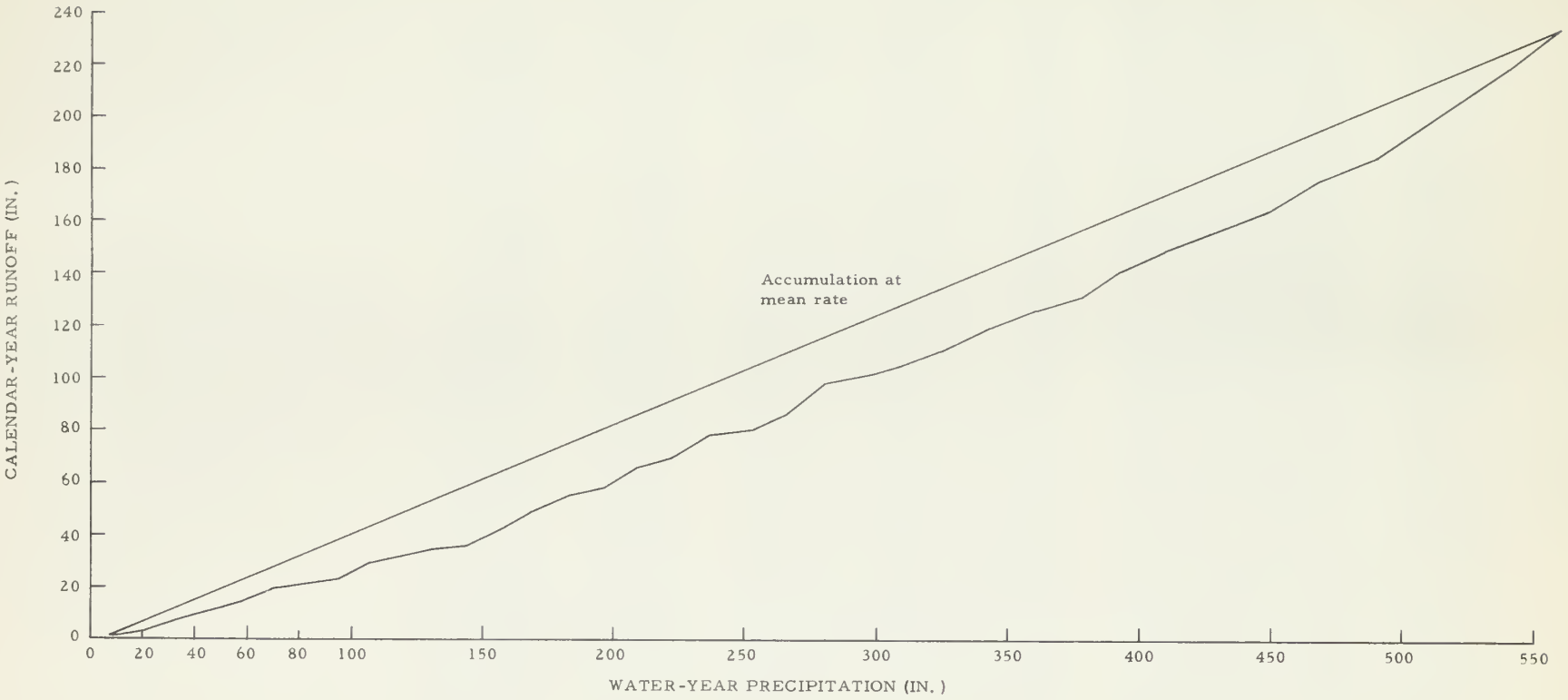


Figure 8. --Double mass plotting of precipitation and streamflow--accumulated by ascending order of precipitation (Santa Fe River).

SUMMARY

The Santa Fe River watershed has a history of heavy use, followed by an extended period of nonuse. The purpose of this study was to find out whether this drastic change in land use affected water yield, and to determine basic precipitation-runoff relationships for that watershed.

The Santa Fe River watershed is located within the Santa Fe National Forest, east and north of the city of Santa Fe, New Mexico, in the Sangre de Cristo mountains. The present gaging station is located at the lower edge of the ponderosa pine type. The area above the station comprises 18.2 square miles of steep and rough terrain, 90 percent of which is covered with conifers. At its headwaters near Lake Peak, the stream is fed by Santa Fe Lake. From that point, at an elevation of 11,500 feet, the stream travels 9.2 miles to the gaging station, with a drop in elevation of 3,800 feet. Flow at the stream gage is regulated by McClure Reservoir, approximately 0.4 mile upstream from the gage.

The stream-gaging records date from April 1913. Since that time there have been three different gaging sites. Because of this, it was necessary to adjust the runoff data to a common area base.

Average precipitation for the Las Vegas and Santa Fe weather stations was used in the analyses, because records of precipitation on the watershed cover only a short period (1947-57). Both weather stations are about 20 miles from the watershed. Las Vegas is east of the mountains, and Santa Fe is west.

Highly significant correlation was found to exist between annual amounts of streamflow and the Las Vegas-Santa Fe precipitation index. It was also found that summer rainfall is a relatively important source of streamflow in the Santa Fe watershed.

A decline in water yield between the period 1914-25, when the Santa Fe watershed had considerable unmanaged use, and the period 1932-57, when the watershed was closed to use, seems to be attributable to a decline in precipitation. This is evident in the double mass analysis.

Differences in water yield, caused by changes in land use, could not be segregated from other differences with the type of data available. Since neither precipitation nor runoff data are accurate, estimates and adjustments were necessary. Statistical analyses detected no significance in decreased water yield after adjusting for precipitation differences.

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